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Business Process versus Human Resources Performance

Jozef Stašák and Eva Škorvagová

Abstract

The contribution deals with qualitative and quantitative analysis of relationship between business processes performance to be investigated (hereinafter BP) versus performance of employees who are interested in that BP functionality hereinafter known as Employees). The qualitative analysis deals with human resources performance psychological aspects, while the quantitative analysis is closely related to BP and Employee performance quantification and modelling. On one hand, the qualitative analysis describes psychological aspects concerned to human resources and the investigated BP performance. On the other hand, the contribution deals with quantifying those relationships with use of linguistic sets, which create basis of business process linguistic modelling (BPLM) approach as well. The PBPL (Principle Business Process Linguistic) Equation is applied in order to create a conceptual model of the objective oriented expert system, which operates over the knowledge base, which contains adequate semantic networks (SNWs) and reference databases (RDBs), while an appropriate inference engine is applied for user communication with that expert system too.

Keywords: Business process, business processes performance, performance of employees, psychological aspects, employee performance quantification, quantifying relationships via linguistic sets, business process linguistic modelling, semantic networks, reference databases

1. Introduction

Any firm, company, institution or enterprise (hereinafter known as the Firm or Company) has its own business mission statement and business objectives, declared in via set of goals postulated within its business strategy, while they are described qualitatively via text in natural language (hereinafter known as TNL text) and quantitatively via set of adequate key performance indicators (hereinafter known as KPI Indicators) [1] In order to fulfil predefined business strategy goals a set of appropriate activities should be provided, while they usually are represented by a set of appropriate business processes, which run within any firm or company. The main goal of the above-mentioned business processes is to generate outputs predefined within the firm or company business strategy with the use of appropriate inputs. However, any business process (BP) is described via its own structure and functionality, where the BP performance plays a role of principal importance as well, while any BP should be managed with respect to set of rules closely relate to process management. The process management is based on the principle that no BP

should be an orphan; it means that that no responsible personality is assigned to the actual BP, while the responsible personality might play a role of the BP owner, operator or executor. With respect to the above-mentioned considerations, we can say there is a direct relation between BP performance and the BP management participant performance as well, while those aspects create an integral part of BP external and internal metrics [2]. On the other hand, the BP metrics identifiers create basis for the firm or company business strategy evaluation. The presented contribution deals with quantification and modelling of relations between BP performance and the performance of human resources who participate at the BP performance management. *The contribution main goal is to design a conceptual and implementation model of an appropriate expert system, the knowledge-base of which content could be created by rules, which regulate the above-mentioned relations, while the rules should enable generating new rules based on existing ones too. However, the rules should respect BP management needs and needs of BP management participants as well.*

In order to fulfil the main goal, several sets of partial aims should be postulated and fulfilled. **The first one** is closely related to quantification of existing and valid relations via adequate formulas and algorithms. **The second one** is concerned with derivation of rules related to representation of knowledge contained within knowledge base. Finally, **the third one** is closely related to the above-mentioned expert system structure definition, where the knowledge-base and inference engine play a role of principle importance too.

2. State of the art

2.1 A set of factors, which determine performance of employees: the qualitative view

2.1.1 General overview

The work is a basic activity for any of us. It enables providing his/her existence, position regard and respect and a man or woman is being satisfied not only within his/her private and social life as well. At present, the work does not mean getting the principal issues for our life only, however we are expecting more, to assert ourselves, to do the work with respect to our imaginations, interests, wishes and expectations too [3]. The work capacity represents only one indicator or human resources efficiency, while that indicator value is being affected not only by organization and technical conditions closely related to the actual work, however by human corporal and mental dispositions as well [4].

The firm or company business efficiency is closely related to performance of individual employees, while a rate to deliver performance and to be satisfied plays a role of principal importance as well. A satisfaction rate related to his/her job seems to be a significant factor, which affects not only his/her working performance, however his/her decision to leave for the actual job, when his/her job balance is negative. However, the negative job balance might lead to change the worker's professional orientation as well, in the case he/she did not identify with his/her professional role [5]. Elaboration of real employee performance description and a comparing it with imagination or concept related to required performance creates an inevitable and integral part of an appropriate motivation program. Simultaneously, the factors with stimulation and motivation function should be mapped. However, there should be described effect of those factors related to motivation and labor behaviour of the firm or company employees as well, while it seems to be very

suitable to detach those facts, which have a favourable and a negative effect related to labour performance. Simultaneously, the factors, which cause dissatisfaction and discomfort, should be mapped too [6].

However, the performance of workers is affected by objective or subjective factors as well, while there might be different criteria concerned with their categorization [7]. Provaznik postulates them as technical, organization, economic and social and situational conditions together with appropriate determinants of a worker or an employee.

However, the personal determinants seem to be most significant from our intension and existing knowledge as well, while the other factors are of the same importance from employee performance point of view. The personal determinants include a great range of assumption for an appropriate work, the employee physical and intellectual assumptions, his/her qualification, personal features, interests and motivation together with employee permanent and actual state (physical and intellectual) play a role of principle importance too.

2.1.2 The objective and subjective nature of factors, which determine performance of workers

The enough labour motivation is closely related to the employee performance and plays a role of principle importance [7]. However, it provides his/her content or discontent in the work as well. There are two significant factors related to the employee labor content or discontent: (a) the first one is, what the work does mean in his/her lifestyle? (b) What the work or labour does mean as a social phenomenon? The labour content as a personality component indicates a level of satisfaction related to needs interconnected to labour or work. However, the labour satisfaction depends on type of employees as well [7, 8]. Herzberg et al. [8] postulate two different level related to the above-mentioned aspect: (a) satisfiers – the factors closely related to the work content (award, satisfaction. Those factors determine the man or woman attitude to the work subject and are closely related to that what he or she is doing. They have a motivating and satisfying effect and they are needed for personal growth, while they enable psychological stimulating and self-realization [7, 9]. In the case, the satisfiers are absent, the worker is not feeling to be satisfied. If the dissatisfaction is away, the satisfiers might be oriented to the employee motivation [4].

The dissatisfies reflect the man's or woman's attitude to the work content and the situation in which the man or woman works, while they are concerned with the widest environmental aspects and awards or wages and generate dissatisfaction without effects related to creation of positive attitudes to the work. They have a protection and maintenance task and they are denoted as hygienic factors as a result of that. However, they generate a working dissatisfaction and a man or woman is feeling a need to avoid troubles as well, while they do not contribute to psychological and personal growth [7]. They do not have a primary demotivation effect; however they have a great deal with work satisfaction or dissatisfaction [4]. Jurkovský (1980¹) postulates appreciation, responsibility, significance and advance of work and a performance as a matter of principle importance. However, those aspects and their perception by employees related to their biorhythmic aspects is a subject of actual research.

¹ In [3].

2.1.3 Relation between functional status of human organism and its performance

The analysis of personal variables related organization efficiency, where the firm or company personal strategy plays a role of significant importance might generate getting to know the employee personality types. At the beginning of milestones concerned with development of views at individual personality, his/her labor capabilities seemed to be the most decisive factor related to his/her labor activities, while fruitfulness of worker was measured by his/her performance and content, a measure of which indicated the firm or company efficiency as well [7] .

A functional status of human organism is not constant within day and several regular swinging might be observed [10]. However, the swinging is denoted as diurnal one is determined by the internal oscillator and biological clocks as well (MINORS, WATERHOUSE, 1986; In [10]). Blake a Colquhoun identified sub-groups of people who indicated their activity in the morning and in the evening and their diurnal temperature model was different than the normal model indicates (BLAKE, 1971; In [11]), (COLQUHOUN, 1960; In [12]). The temperature of people active in the morning is growing, reaches a peak and decreases in the day, while the people active in the evening indicate the delayed temperature model. An existence of different models related to activity of people in the morning and in the evening is not surprising and was confirmed, when investigating individual people. An importance of pre-determined diurnal preferences in the work was the subject of the actual research.

2.2 The factors, which affect the employee performance: quantitative view

2.2.1 Business processes: structure and functionality

A set of business processes running in the firm or company is being judged and evaluated, when investigating that firm management system internal structure, while the *process control* should be respected and that term semantic meaning is explained within introduction of our contribution.

However, the management processes should be considered and respected, when considering the business process types and classes as well, while the special group employees participates at the functionality. They are denoted as - *the managers*. When considering the business process (BP) horizontal structure, the business process functions (BPFs) play a role of principal importance, while the BP horizontal structure consists of appropriate BPF sets, which seem to be significant at BPF modelling operations. There might be applied different approaches, while one of them is denoted as BP linguistic modelling approach - hereinafter known as BPLM approach [13], which is based the postulate that any BPF might be represented via logical sentence, which create basis of *text in natural language* (hereinafter known as TNL Text²), while that sentence is defined via set denoted as the *linguistic set* [14, 15].

2.2.2 Business process: external and internal metrics

In general, the BP metrics term has a different semantic meaning than a semantic meaning of Business Metrics term, while the *Business Metrics* term indicates that any component of the firm or company business might be quantified and measured and the term *BP external and internal metrics* is concerned with horizontal structure

² The TNL text might be written in any language, English, Slovak, Czech, as for instance.

element quantification and measurement, which creates an integral part of actually investigated BP running in the firm or company. On one hand, when considering the *Business Metrics term*, the firm or company business performance indicator values might be quantified and measured - return of investment or employee performance, as for instance. On the other hand, the term *BP external and internal metrics* might indicate a quantification and measurement such variables like technological device or technological tool performance, which create an integral part of the investigated business process, as for instance. However, both above-mentioned metrics types create an integral part of the branch denoted as Business Intelligence as well, while the main aim of any BPF and BP is to generate outputs pre-defined within the firm or company business strategy based on appropriate inputs and the *BP outputs and inputs* create an integral part of **BP external metrics** and the data and information concerned to performance of human resources, technological devices and technological tools who participate at BP functionality and performance create an integral part of the **BP internal metrics**. In order to generate the above-mentioned BP outputs based on appropriate inputs an engine denoted as **transformation engine** should exist, while *transformation operators (TOP)*, *human resources (HR)*, *technological devices (DEV)* and *tools (TOOL)* create an integral part of the **BP internal metrics** [16].

2.2.3 Human resources as an integral part of business process metrics

In a previous section, we have mentioned the business process internal and external metrics [2] represented by adequate linguistic sets, while the linguistic set concerned with human resources performance data $\{[HR_performance(i, j)]\}$ creates an important part of internal BP metrics too. As mentioned above, production devices, represented by $\{[Dev(i, j)]\}$ linguistic set and tools represented by $\{[Tool(i, j)]\}$ linguistic set create an integral part of BP internal metrics as well, while they will not be discussed within that contribution and considered to be the empty sets, $\{[Dev(i, j)]\} = \emptyset$ and $\{[Tool(i, j)]\} = \emptyset$.

2.2.4 Quantification and linguistic modelling of business process structure and functionality

The term BP structure quantification means a mathematical description related to BP static as static aspects. However, the BP static aspect interpretation via linguistic sets is closely related to the business process to be investigated as well.

With respect to the postulate that any business process might be quantified via linguistic sets, which represent, the BP outputs, inputs and BPFs formula (1) can be postulated, while the

$$BP(i) = \prod_{j=1}^{m_1} \Pi BPF(i, j) \quad (1)$$

where

$i = 1, 2, \dots, n$ - index, which indicates the investigated BP serial number within superior vertical structure.

$j = 1, 2, \dots, m_1$ - index, which indicates a serial number of BPF within BP to be investigated.

BPF linguistic sets contain subsets concerned with human resources $[Hr(i, j)]$, production devices $[Dev(i, j)]$ and production tools $[Tool(i, j)]$ and formula (2) and (3) are postulated

$$\{[BP(i)]\} = \{[Pe(i)]\} \quad (2)$$

$$\{[Pe(i)]\} = \{[Hr(i,j)], [Dev(i,j)], [Tool(i,j)]\} \quad (3)$$

Further considerations related to BPF and BP structure quantification will be based on **linguistic sets**, which create basis of BPLM [1].

2.2.5 The PBPL Equation plays a role of basis related to quantification and linguistic modelling of BP and BPF structure and functionality

In general, any BPF is represented by three linguistic sets; see also formulas (2), (3). Let us consider a linguistic set of pre-defined outputs $\{[Res1(i,j)]\}$ and a set of adequate inputs, $\{[Petx(i,j)]\}$, the **Principle Business Process Linguistic Equation** – hereinafter known as PBPL Equation **might** be introduced, while its basic form is postulated via formula (4) and will be applied for further BPF and BP quantification and linguistic modelling [17].

$$\{[Petx(i,j)]\} \otimes \{[BP(i,j)]\} = \{[Res1(i,j)]\} \quad (4)$$

It is known, that the PBPL Equation has an endless number of solutions, while any solution is closely related to its application at BPFs and BP linguistic models (hereinafter known as BPLM approach). However, that equation will be applied for creation of BP functionality model, which describes relationship between the BP performance and production human resources (see also Section 4).

3. Research methods

Two approaches have been selected, when investigating the modelled BP performance and a performance of employees interested in that BP functionality. The first approach is denoted as a qualitative and second is denoted as quantitative one.

When applying the qualitative approach in order to investigate the above-mentioned relationship, we have postulated the aim to catch a labor motivation in the context of motivating elements and hygienic factors, which are acting at labor motivation related to works published by [8] In [7], and [3].

With respect to those works, we have postulated two hypotheses: (a) *There is a difference between early-maturing and vesper tine chronotype of workers in a subjective labor performance perception during the week related to CTQ³ Scale* [18].

(b) *There is a difference between early-maturing and vesper tine chronotype of workers in a subjective labor performance perception during the 24 hours related to CTQ* [18].

Eighteen employees (100 %) created a research subject. As for personal structure, there were: manager, deputy of manager, five professors, four associated professors and seven assistant professors. The formulated hypothesis related to the above-mentioned research described in that contribution created a good basis for quantification of relations between business process performance and those employee performance who were interested in that business process. With respect to postulated hypothesis and research described in those results created basis for performance quantification relationships between the BP to be investigated and performance quantification of employees interested in the above-mentioned BP functionality (performance). Appropriate linguistic sets have been applied in order

³ CTQ - Circadian Type Questionnaire.

to quantify the pre-defined relation, while those sets create an integral part of the PBPL Equation basic form PBPL [15] while the modified PBPL Equation form has been derived in order to enable applying it for quantification of pre-defined relation. Subsequently, we started looking for the modified PBPL Equation solution, the results of which were linguistic sets, the content of which has been transformed to adequate semantic networks (SNWs) and reference databases (RDBs), while they created a good basis for knowledge representation concerned with the investigated relationship. Simultaneously, an adequate expert system structure has been designed [1], while the knowledge base contains SNWs and RDBs. No analytical approach might be applied, when looking for the PBPL Equations solution and the approach based on graphs and tables was applied, as a result of that. However, it enables representing the relationship between BP performance and performance of employees interested in its functionality and performance as well.

4. Results and discussion

4.1 The factors, which affect business process performance related to employee performance: qualitative view

The personal dimensions represent an internal potential of any man or woman, while they play a role of principal importance, his/her labor career. When considering the labor aspects, they are closely related to following questions: "What the man or woman is able?", "What the man or woman does want?", "What the man or woman is?" A structure of personal image might be postulated, when combining those aspects, while the structure is unique for any personality and includes many different and specific features closely related to that personality only. However, the labor requirements might greater than, the disposals of man or woman are as well, while a conformity between set of labor requirement and set of the employee capabilities might create adequate labor conditions [7].

A fact, that the actual working or labor time in the day seems to be more suitable than the other one is given by regular variations being internally generated by functional organism states within 24 hours of the day. However, the above-mentioned variations exist not only because of psychological reasons, but they are observed and verified within all physiological functions as well, despite that the external conditions might be constant or unchanged. On the other hand, the diurnal variations cannot be described with use of one universal curve, because different functions indicate various course or progress and sometimes that course or progress might indicate a contradictory visual representation.

Moreover, the performance course or progress in the day depends on labour activity nature, as for instance, because the works with different requirements may indicate quite different performance course or progress. As a result of that, the most suitable time intervals for the actual work cannot be determined generally, because they are dependent on the labor or working activity type and appropriate time requirements as well.

However, individual differences also represent the next factor, which plays a significant role related to labor or working performance, while the phase displacement of biorhythmic curve to earlier or later day time seems to be the most significant aspect and that aspect correlates with the man or woman morning or evening Chrono type in a great deal. The preference of an appropriate day time interval seems to be more significant, when considering the above-mentioned individual differences.

We can determine less or more suitable time intervals for the work in the day, while we can support an opinion presented by Vašáková [3] who says that a labor motivation plays a role of principle importance there, while that motivation is a process, which is initiated and enables achieving the pre-defined aim and where or motional forces of individual man or woman are getting started and running in order to achieve that pre-defined aim as well. When considering the hygienic factors, the interpersonal relations, work conditions, employment reliability, relations to supervisors, position among people, wages, the firm or company culture and working check and control seem to be a matter of principal importance, while the motivation seems to be the principal step to be satisfied. With respect to that work results, the firm or company should place emphasis on motivation and satisfaction and a good feeling of its employees. However, that statement corresponds to research results provide by [3] as well.

With respect to the actual research results and findings achieved by Jackson and Gerard [19], further research related to diurnal Chrono types work performance is recommended and should be extended. On the other hand, there is needed a long-term research in order to identify pre-dispositions, which affect a personality, its working performance and social behavior as well. A set of such research results creates a good basis for quantification and modelling relations between performance of business processes running in the actual firm or company and a performance of employees interested in a functionality of those processes (human resources), while it is known that human resources represent an important component of business process metrics too. The problems related to solution of the above-mentioned relation represent a subject of those contribution further sub-chapters [2].

4.2 The factors, which affect business process performance related to employee performance: quantitative view

4.2.1 Derivation of PBPL Equation concerned with relation between investigated business process performance and the performance of employees interested in that BP functionality

With respect to qualitative considerations contained within material denoted as “Chrono psychological aspects of labour performance in the world of labour psychology and management informatics” the objective factor attributes and their values might be stored in appropriate linguistic sets, which have an adequate hierarchical structure.

Let us consider the $\{[HR^4_performance(i, j)]\}$, where $i = 1...n$ – index – indicates a serial number of BP to be investigated and modelled, which appropriate human resources are assigned to $j = 1, 2 \dots m_5$ – the linguistic set serial number, which creates an integral part of

$\{[HR_performance(i, j)]\}$ linguistic set while formula (5) might be postulated⁵

$$\{[HR_performance(i, j)]\} = \{[a11(i, j_1)], [a21(i, j_2)], [a31(i, j_3)], [a41(i, j_4)]\} \quad (5)$$

⁴ $\{[HR_performance(i, j)]\}$ – performance of human resources (employees).

⁵ $[a11(i, j_1)] = HR_01$ Labour content, $[a21(i, j_2)] = HR_02$ Labour motivation, $[a31(i, j_3)] = HR_03$ Labour conditions, $[a41(i, j_4)] = HR_04$ Employee capabilities.

We shall apply the PBPL Equation in order to quantify a relation between performance of business to be investigated and performance of employees interested in that BP functionality, while its basic form is represented by formula (6)

$$\{[Petx(i, j')]\} \otimes \{[Pe(i, j)]\} = \{[Res(i, j)]\} \quad (6)$$

The $\{[Petx(i, j')]\}$ and $\{[Res(i, j)]\}$ create an integral part of external metrics related to business process quantified via $\{[Pe(i, j)]\}$ and the relationship between $\{[Petx(i, j')]\}$ and $\{[Res(i, j)]\}$ will not be investigated and discussed within that article and $\{[Petx(i, j')]\}$ linguistic set is considered to be the empty one $\{[Petx(i, j')]\} = \emptyset$ and we shall discuss the relationship between $\{[Pe(i, j)]\}$ and $\{[Res(i, j)]\}$ linguistic sets $\{[Pe(i, j)]\}$ and $\{[Res(i, j)]\}$, while formula (7) might be postulated

$$\{[Pe(i, j)]\} \Leftrightarrow \{[Res(i, j)]\} \quad (7)$$

However, the $\{[Pe(i, j)]\}$ linguistic set consist of three subsets as well, while formula (9) might be postulated.

$$\{[HR_performance(i, j_1)] [Pe(i, j)]\} = \{[Dev(i, j'')], [Tool(i, j'')], [HR_performance(i, j_1)]\} \quad (8)$$

Because of that, we shall investigate and discuss the relationship between business process performance based on output products represented by so called good products, repair products and waste products⁶ and the data concerned to those products are stored within $\{[Res(i, j)]\}$ linguistic set, the linguistic subsets $[Dev(i, j'')]$ and $[Tool(i, j'')]$ are considered to be empty as well. With respect to the above-mentioned assumptions, the equation represented by formula (8) is being reduced, while formula (9) might be postulated

$$\{[HR_performance(i, j_1)]\} \Leftrightarrow \{[Res(i, j)]\} \quad (9)$$

Now, let us try explaining structure and content of $\{[HR_performance(i, j_1)]\}$ linguistic set, the structure and content of $\{[Res(i, j)]\}$ linguistic set is explained within Section 4.2.3. In order to achieve that, the following consideration is postulated.

4.2.1.1 Consideration no.1

The $\{[HR_performance(i, j_1)]\}$ has a hierarchic structure, while the linguistic subsets at the first hierarchic level are defined, with respect to formulas (10), (11), (12) and (13)

$$[a11(i, j_1)] = HR_01 Labour content \quad (10)$$

$$[a21(i, j_2)] = HR_02 Labour motivation \quad (11)$$

$$[a31(i, j_3)] = HR_03 Labour conditions \quad (12)$$

$$[a41(i, j_4)] = HR_04 Employee capabilities \quad (13)$$

⁶ A semantic meaning of terms good products, repair products and waste products is explained within further section of that contribution.

Any element of that set $a_{11}, a_{21}, a_{31}, a_{41}$ is represented by adequate ordered pair (see also formula (14))

$$a_{11}(i, \alpha(j_6)) = (a_{11atr}(i, \alpha(j_6)), a_{11atrval}(i, \alpha(j_6))) \quad j_6 = 1, 2, \dots, m_6 \quad (14)$$

$(a_{11atr}(\alpha(j_6)))$ - is the investigated variable attribute

$(a_{11atrval}(\alpha(j_6)))$ - is the investigated variable attribute value

However, the above-mentioned attributes and attribute values has so called time dimension,⁷ while formula (8) might be postulated

$$a_{11}(i, \alpha(j_6)) = (a_{11atrval}(\alpha(i, j_6)), t(j_{10})) \quad (15)$$

If appropriate statistic values of $(a_{11atrval}(\alpha(i, j_6)), t(j_{10}))$ attributes according to $t(j_{10})$ index are being generated (it means average – Avg and extend of variation Vaprp, formula (15) is being transformed to formulas (16) and (17)

$$\{[b_{11}(i, j_1)]\} = \{[(a_{11atr}(\alpha(j_6))), [Avg(a_{11atrval}(\alpha(i, j_6))), [Varp(a_{11atrval}(\alpha(i, j_6)))]]\} \quad (16)$$

$$\{[b_{11}(i, j_1)]\} \subseteq \{[Petx(i, j')]\} \quad (17)$$

As mentioned above the $\{[Petx(i, j')]\}$ linguistic set is considered to empty one and $\{[Petx(i, j')]\} = \emptyset$, however that set contains elements concerned to material inputs related to business process to be investigated and modelled as well, while it would be suitable to define structure of those elements (see also Consideration no. 2).

4.2.1.2 Consideration no. 2

The aim of business process to be investigated and modelled is to generate pre-defined output products, while a set of appropriate material outputs are required in order to achieve that aim.

It means, the business process to be modelled represented by $\{[Pe(i, j)]\}$ linguistic set generates pre-defined output products quantified via $\{[Res1(i, j)]\}$ linguistic set based on adequate material inputs quantified via $\{[Mat(i, j), (j=1, 2, \dots, m_1)]\}$ linguistic set, while formula (18) might be postulated

$$\forall \{[Pe(i, j)]\} \exists \{[Res1(i, j)]\} \text{ and } \{[Mat(i, j), (j=1, 2, \dots, m_1)]\} \Leftrightarrow \{[Mat(i, j),]\} \otimes \{[Pe(i, j)]\} = \{[Res1(i, j)]\} \quad (18)$$

On the other hand, the $\{[Mat(i, j), (j=1, 2, \dots, m_1)]\}$ applied for quantification of material inputs contains elements, closely related to attributes and values concerned with individual materials represented by $[(Mat_{atritem}(i, j_1, t_{10}), \text{material attribute item and } [(Mat_{atrvalue}(i, j_1, t_{10}), \text{material attribute value with adequate time dimension (see also formula (19)). Furthermore, that linguistic set contains subset, the content of which material attribute statistic values } Avg(Mat_{atrvalue}(i, j_1)), Vaprp(Mat_{atrvalue}(i, j_1)) \text{ calculated by an appropriate time dimension, while formula (19) might be postulated}$

⁷ The term attribute time dimension is expressing the time intervals, when the values have been measured.

$$\begin{aligned} & \forall \{ [\text{Mat} (i, j)], (j = 1, 2, \dots m_1) \} \exists \{ [\text{Mat}_{\text{atr}} (i, j_1)], j_1 = 1, 2 \dots m_3 \} \Leftrightarrow \{ [\text{Mat}_{\text{atr}} (i, j_1)] \} \\ & = \{ \left[\left(\text{Mat}_{\text{atritem}} (i, j_1, t_{10}) \right), \left[\left(\text{Mat}_{\text{atrvalue}} (i, j_1, t_{10}) \right), [\text{Avg} (\text{Mat}_{\text{atrvalue}} (i, j_1))], \right. \right. \\ & \quad \left. \left. [\text{Vaprp} (\text{Mat}_{\text{atrvalue}} (i, j_1)) \right] \right\} \end{aligned} \quad (19)$$

As mentioned above, we shall investigate a relation between modelled business process performance and performance of employees interested in functionality of that process (see also formula 8), where the $\{[\text{HR_performance} (i, j)]\}$ and $\{[\text{Res1} (i, j)]\}$ linguistic set play a role of principle importance, while formula (20) might be postulated

$$\begin{aligned} \text{Hr} (i, j'') &= \{[\text{HR_performance} (i, j)]\} \\ &= \{[a_{11}(i, j_1)], [a_{21}(i, j_2)], [a_{31}(i, j_3)], [a_{41}(i, j_4)]\} \end{aligned} \quad (20)$$

Now, we shall consider the PBPL Equation and we shall replace the $\{[\text{Petx} (i, j')]\}$ linguistic set by $\{[\text{Mat}_{\text{atr}} (i, j_1)]\}$ linguistic set (see also formula 23) and the $\{[\text{Pe} (i, j)]\}$ linguistic set by $\{[\text{HR_performance} (i, j)]\}$ linguistic set (see also formula (24) and (25)) and the $\{[\text{Res} (i, j)]\}$ by $\{[\text{Outbpf} (i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste} (i), j_3))]\}$ linguistic set (see also formula (26) and (27)), the PBPL Equation (see also formula 7) is getting a new form, while formula (21) might be postulated

$$\begin{aligned} & \{ \left[\left(\text{Mat}_{\text{atritem}} (i, j_1, t_{10}) \right), \left[\left(\text{Mat}_{\text{atrvalue}} (i, j_1, t_{10}) \right), [\text{Avg} (\text{Mat}_{\text{atrvalue}} (i, j_1))], \right. \right. \\ & \left. \left. [\text{Vaprp} (\text{Mat}_{\text{atrvalue}} (i, j_1))] \right] \right\} \otimes \{ [a_{11}(i, j_1)], [a_{21}(i, j_2)], [a_{31}(i, j_3)], [a_{41}(i, j_4)] \} \\ & = \{ [\text{Outbpf} (i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste} (i), j_3))] \} \end{aligned} \quad (21)$$

Formula (21) indicates a modified form of PBPL Equation, which might be applied for quantification of relationship: investigated business process performance versus performance of employees interested in that business process functionality.

4.2.2 Solution of PBPL Equation concerned with relation between investigated business process performance and the performance of employees interested in that BP functionality

However, analytical solution of the PBPL Equation represented by formula (21) is not possible. As a result of that, we must start that solution with needs of metrics related to actual BPF and BP subsequently. Therefore, we shall apply an abbreviated form of PBPL Equation (see also formula 8) because the $\{[\text{Petx} (i, j')]\} = \emptyset$. With respect to those assumptions is being converted into simplified version (see also formula 22)

$$\begin{aligned} & \{ [a_{11}(i, j_1)], [a_{21}(i, j_2)], [a_{31}(i, j_3)], [a_{41}(i, j_4)] \} \\ & = \{ [\text{Outbpf} (i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste} (i), j_3))] \} \end{aligned} \quad (22)$$

However, analytical solution of the PBPL Equation represented by formula (31)-(33) is not possible as well, therefore while we shall apply so called **semantic network and rule approach**, which is based on so called **immediate** and **interval semantic network**. We shall explain a semantic meaning of both terms within Consideration no. 3.

4.2.2.1 Consideration no. 3

Because, the subject of investigation is a relation between modelled business process performance and performance of employees interested in that BP functionality, we might apply PBPL equation modified with respect to formula (23)

$$\begin{aligned} & \{ [a_{11}(i, j_1)], [a_{21}(i, j_2)] \}, [a_{31}(i, j_3)], [a_{41}(i, j_4)] \} \\ & = \{ [\text{Outbpf}(i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste}(i, j_3)))] \} \end{aligned} \quad (23)$$

Furthermore, let us make the following assignments

$$\{ [a_{11}(i, j_1)], [a_{21}(i, j_2)] \}, [a_{31}(i, j_3)], [a_{41}(i, j_4)] \} = \{ [a_{14}(i, j_2)] \} \quad (24)$$

$$\{ [\text{Outbpf}(i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste}(i, j_3)))] \} = \{ [a_{15}(i, j_2)] \} \quad (25)$$

With respect to formula (31)-(33) and formulas (23) and (24) formulas (26) and (27) might be postulated

$$\{ [a_{15}(i, j_2)] \} \approx \{ [a_{14}(i, j_2)] \} \quad (26)$$

$$\{ [a_{15}(i, j_2)] \} = \{ [k_{54}(i, j_2)] \} \otimes \{ [a_{14}(i, j_2)] \} \quad (27)$$

which represent a basic relationship between investigated BP performance and performance of employees interested in that BP functionality. Because a strict analytical solution of equation (4.20b) is not possible, it is needed to introduce the $\{ [k_{54}(i, j_2)] \}$ linguistic set, which contains coefficients determining a relation between items, which represent performance of the investigated BP and items, which represent performance of employees interested in functionality of that BP.

With respect to that, we have to describe $\{ [\text{Outbpf}(i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste}(i, j_3)))] \}$ linguistic set content, while each of the subordinated set contains only one element concerned to number of good, repaired and waste BP output products, while that fact might be represented by adequate semantic network (see also **Figure 1**).

The similar approach could be applied, when quantifying a content of Employee performance linguistic set, however that structure is more complicated as well, while the subsets at hierarchic level no.1 are closely related to labor content, labor motivation and labour conditions and employee capabilities.

4.2.3 Time instant semantic network

The $\{ [\text{Outbpf}(i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrrepair}(i, j_3)), (\text{nvyrwaste}(i, j_3)))] \}$ linguistic set, which enables quantifying the investigated business process performance and the $\{ [\text{Vyk_zam}(i, a_{21a}(i), a_{21b}(i), a_{31}(i), a_{41}(i))] \}$ linguistic set create an integral part of semantic network (see also **Figure 2**), which enables answering the question “How the investigated BP performance is affected by performance of employee interested in that BP functionality (performance)? However, that relation is visualized within instant of time as well, and therefore that type of semantic network might be denoted as **time instant semantic network**.

4.2.4 Time interval semantic network

If there is a requirement to establish the semantic network, which visualizes appropriate items and their values within pre-defined time interval, adequate

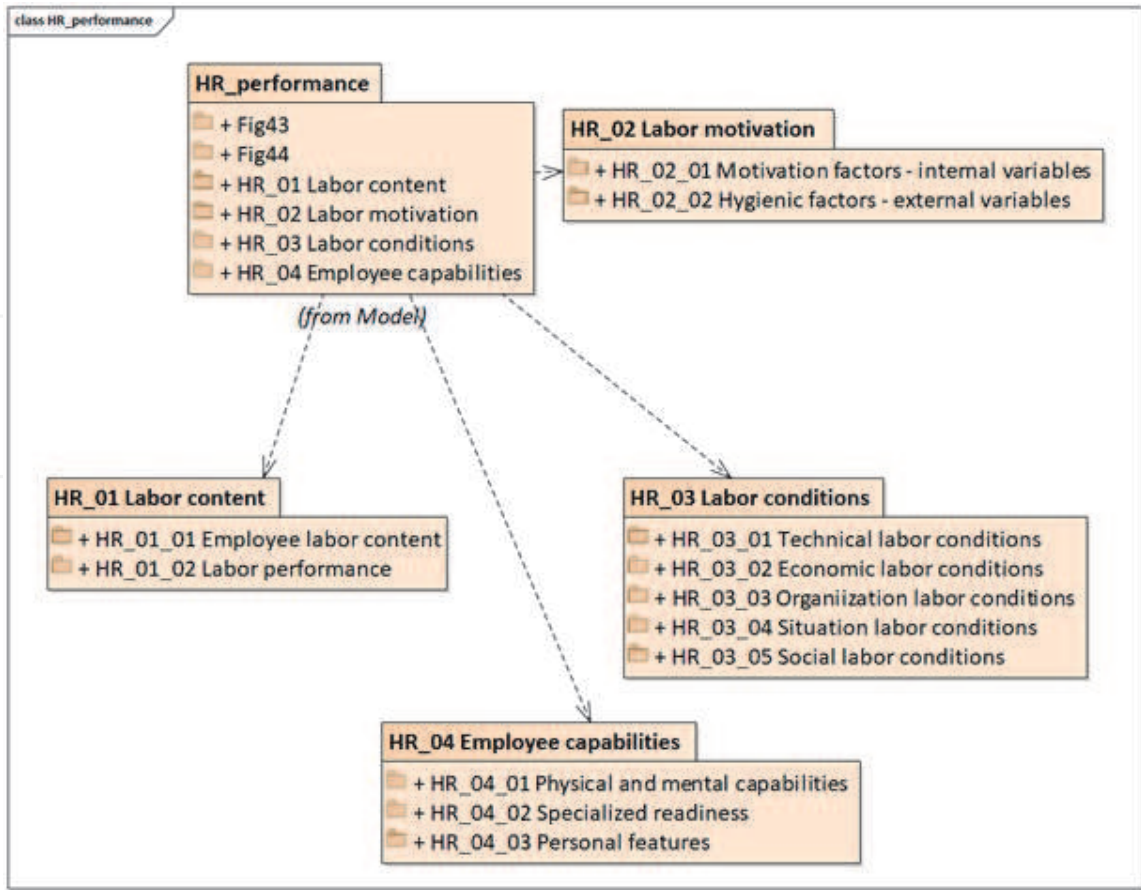


Figure 1.
Structure and functionality of the ES_BP_HRP model Source: The Authors.

statistic values – average Avg and extend of variation Vaprp should be determined, which are closely related to $(\text{nvyrgood}(i, j_3)), (\text{nvyrrepair}(i, j_3)), (\text{nvyrwaste}(i, j_3))$ values as well as to items and values contained within a21a, a21b, a31 a a41 linguistic sets and an adequate semantic network might be created subsequently. This type of semantic network is denoted as **time interval semantic network**.

The similar approach should be applied, when quantifying the linguistic set employee performance; however a structure of that linguistic set is more complicated. The subsets $[a11(i, j_1)] = \text{HR_01 Labor content}$, $[a21(i, j_2)] = \text{HR_02 Labor motivation}$, $[a31(i, j_3)] = \text{HR_03 Labor conditions}$ and $[a41(i, j_4)] = \text{HR_04 Employee capabilities}$ at the first hierarchic level contain appropriate items and values. When comparing it with time instant semantic network, there is one difference. We have to determine appropriate statistic values Avg and Vrozp concerned to the above-mentioned items and values and after that we are allowed to create the time interval semantic network.

The $\{[\text{Outbpf}(i, (\text{nvyrgood}(i, j_3)), (\text{nvyrrepair}(i, j_3)), (\text{nvyrwaste}(i, j_3)))]\}$ linguistic set, which enables quantifying the investigated business process performance and the $\{[\text{Vyk_zam}(i, a21a(i), a21b(i), a31(i), a41(i))]\}$ linguistic set create an integral part of semantic network which enables answering the question “How the investigated BP performance is affected by performance of employee interested in that BP functionality (performance) within appropriate time interval?”, while the above-mentioned statistic values should be respected. However, the above-mentioned relation is visualized within adequate time interval.

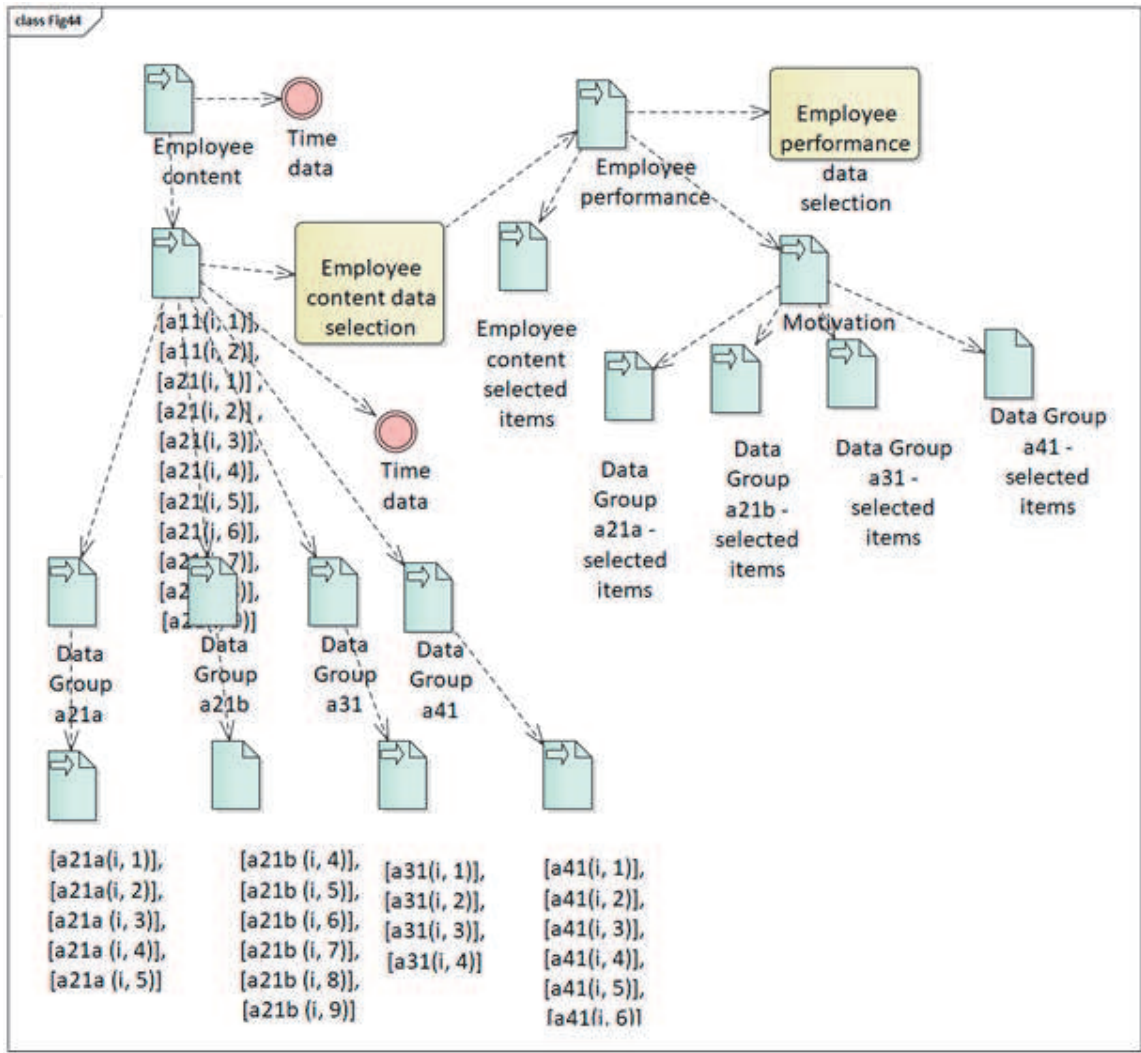


Figure 2.
The Vyk_zam (Employee performance) content within instant semantic network Source: The Authors.

4.2.5 Rule generation versus time instant and time interval semantic networks

Before, is getting started a set of appropriate data should be collected. Data, which create content of $\{[\text{Outbpf}(i, (\text{nvyrgood}(i, j3)), (\text{nvyrrrepair}(i, j3)), (\text{nvyrrwaste}(i, j3))]\}$ seem to be most significant, however the data contained within $\{[\text{Vyk_zam}(i, a21a(i), a21b(i), a31(i), a41(i))]\}$ linguistic sets plays a role of principle importance as well.

4.2.5.1 Investigated BP performance – determination of measured unit number

When providing evaluation of investigated BP performance, a number of measured units is represented by an appropriate integer value $\text{nvyrrrepair}(i, j3)$, $(\text{nvyrrwaste}(i, j3))$. However, that type of representation usually does not correspond to representation needs within semantic network. As a result of that, we introduce so called ratio value $xvyrgood(i)$, $xvyrrrepair(i)$ a $xvyrrwaste(i)$, which might be calculated with respect to formulas (28), (29) and (30)

$$xvyrgood(i) = \frac{\text{nvyrgood}(i, j3)}{(\text{nvyrgood}(i, j3)) + \text{nvyrrrepair}(i, j3) + \text{nvyrrwaste}(i, j3)} \quad (28)$$

$$xvyrrrepair(i) = \frac{\text{nvyrrrepair}(i, j3)}{(\text{nvyrgood}(i, j3)) + \text{nvyrrrepair}(i, j3) + \text{nvyrrwaste}(i, j3)} \quad (29)$$

$$\text{xvyrwaste}(i) = \frac{\text{nvyrwaste}(i, j3)}{(\text{nvyrgood}(i, j3) + \text{nvyrrrepair}(i, j3) + \text{nvyrwaste}(i, j3))} \quad (30)$$

The results are represented by decimal numbers, as a rule.

4.2.6 Equations, which enable rule generation

The relationship between investigated BP performance and performance of employee interested in BP functionality might be quantified via formulas (4.20a and 4.20b)

$$\{[a15(i, j2)]\} \approx \{[a14(i, j2)]\} \quad (31)$$

$$\{[a15(i, j2)]\} = \{[k54(i, j2)]\} \otimes \{[a14(i, j2)]\} \quad (32)$$

where

$\{[a15(i, j2)]\}$ is a linguistic set, which contains data concerned with investigated BP performance

$\{[a14(i, j2)]\}$ is a linguistic set, which contains data concerned with performance of employee interested in BP functionality

$\{[k54(i, j2)]\}$ is a linguistic set, which contains data concerned with the above-mentioned relation dynamics

Furthermore, we assume that the performance of employee interested in investigated BP performance is given by measure of employee content and motivation, while formula (33) might be postulated

$$\{[a11(i, 1)]\} = \{[a11(i, j1)], [a11(i, j4)]\} \quad (33)$$

Where

$[a11(i, j1)]$ – is a measure of employee content

and

$[a11(i, j4)]$ – is a measure of employee motivation

An outgoing point for rule generation is the **time interval semantic network**, which contains appropriate attributes together with their adequate statistic values.

With respect to inputs postulated within time instant and time interval semantic network two types of rules might be generated: (a) the basic rule concerned with time instant semantic network (see also Rule no.1) and (b) the basic rule concerned with time interval semantic network (see also Rule no. 2).

Rule no. 1 - the basic rule concerned with time instant semantic network

$$\begin{aligned} &\text{IF Date1}(i, k) \text{ and Time1}(i, k) = \text{Date2}(i, k) \text{ and Time2}(i, k) \\ &\text{and } [a21(i, k, \text{Date2}, \text{Time2})] \in [a21a(i)] \text{ THEN } (\text{Typ_vystupu}(i, k)) \\ &= (\text{Počet_m.j}(i, k)) \in \text{Vyk_skum_BP} \end{aligned}$$

Where

$k = 1 \dots m1$ is the ordinal number

$i = 1 \dots n$ is the ordinal number of investigated BP within set of other business processes

Date1(i, k) – date of made measurement

Time1(i, k) - time of made measurement

Output type(i, k) – output type – good, repaired, waste

M. u. number(i, k) – number of units related to actual output

$[a21a(i)]$ - linguistic set.

Rule no.2 - the basic rule concerned with time interval semantic network

IF Date1 (i, k1a) and Time1 (i, k1a) = Date2 (i, k1a) and Time2 Avg(a21(i, k1a))
 $\in [a21a(i)]$ THEN (Typ_vystupu (i, k1a)) = Avg ((Počet_m.j (i, k1a))) \in
 Vyk_skum_BP

IF Date1 (i, k1a) and Time1 (i, k1a) = Date2 (i, k1a) and Time2 Var_rozp(a21(i, k1a)) $\in [a21a(i)]$ THEN (Typ_vystupu (i, k1a)) = Var_rozp ((Počet_m.j (i, k1a))) \in
 Vyk_skum_BP

k1a = k2-k1 - k1 – the beginning of measurement time interval t1, t2

k2 – the end of measurement time interval t1, t2 [a21(i, k1a,

Date2, Time2, Avg ((M.u. number (i, k1a)))]

Vyk_skum_BP – the semantic set, which contains data closely related to performance of employee interested in investigated BP functionality

However, further rules might be derived based on Rule no.1 and Rule no. 2 as well.

4.3 Investigated BP performance versus performance of employee interested in that BP functionality: The objective oriented expert system - ES_BP_HRP

The previous sub-section concerned that chapter deal with theoretical aspects related to investigated BP performance and performance of employee interested in that BP functionality and the result is a conceptual model related to the above-mentioned objectives. However, this section deals with implementation of the conceptual model and a result should have a shape of the objective oriented expert system, which should enable to find a response to the question “How individual psychological factors affect the investigated BP performance and a performance of employees interested in that BP functionality” as well. On the other hand, that expert system plays a role of knowledge-based support tool for the above-mentioned investigated business process too.

4.3.1 The ES_BP_HRP_02 system: structure and functionality

The ES_BP_HRP_02 system structure consists of two subsystems typical for any knowledge-based or expert systems denoted as ES_BP_HRP_02_01Knowledge Base and ES_BP_HRP_02_02 Inference Engine. When considering the ES_BP_HRP_02_01Knowledge Base, the knowledge stored there are represented based on appropriate semantic networks (SNWs) and reference databases (RDBs), while the RDBs contain data and information, based on which adequate SNWs are being generated.

4.3.2 The ES_BP_HRP_02 expert system knowledge base: RDBs component

The data stored within reference databases have the
 $\{[ES_BP_HRP_02_01_02_02 \text{ Výstupy_Outputbpf (i, j)}]\}$ linguistic set nature, which consist of three subordinated linguistic sets $[ES_BP_HRP_02_01_02_01_01 \text{ Output_OK (i, j)}]$ ⁸, $[ES_BP_HRP_02_01_02_01_02 \text{ Output_REPAIR (i, j)}]$ ⁹ and

⁸ Those subset elements are concerned with those output products, which meet the pre-defined criteria in a full range and are denoted as – good output products.

⁹ Those subset elements are concerned with those output products, which meet the pre-defined criteria in a full range, however they might be repaired so that, they can be good output products and they are denoted as the repaired output products.

[ES_BP_HRP_02_01_02_01_03 Output_WASTE (i, j)],¹⁰ while a content of those linguistic sets is described in section denoted as Generation of rules – data -acquisition - time instant and time interval semantic network.

4.3.3 The ES_BP_HRP_02 expert system knowledge base: SNWs component

The SNWs are a direct representant of knowledge contained in the knowledge base, the above-mentioned expert system operated over. They contain linguistic sets, which are directly concerned to objectives, which deal with designed expert system. If the designed expert system is concerned with relationship between investigated BP performance and performance of employees interested in that BP functionality, the above-mentioned SNWs contain the following linguistic sets:

- ES_BP_HRP_02_01_01 Performance, which contains linguistic sets concerned with performance of BPFs, the investigated BP consists of, denoted as ES_BP_HRP_02_01_01_01.....(m) Performance (see also **Figure 1**)
- ES_BP_HRP_02_01_01_01_01_03_01 Human Resources Performance, which contains the linguistic subsets concerned to employee content and employee motivation ES_BP_HRP_02_01_01_01_01_03_02, while that linguistic set consists of the following subsets:
 - ES_BP_HRP_02_01_01_01_01_03_02_01 Personal motivation,
 - ES_BP_HRP_02_01_01_01_01_03_02_02 Environmental motivation
 - ES_BP_HRP_02_01_01_01_01_03_02_03 Labor conditions
 - ES_BP_HRP_02_01_01_01_01_03_02_04 Personal capabilities

As for elements, which content of the above-mentioned linguistic sets, they are described within **Tables 1** and **2**. However, there are linguistic sets, which create an integral part RDB With respect to those assumptions Time Instant and Time Interval Semantic Networks are defined.

4.3.4 Inference engine

The inference engine plays a role of the communication tool with actual expert system for authorized user and consists of the following components (a) component, which provides retrieval and presentation of the knowledge base content based on general and detailed knowledge requirement (hereinafter known as KB content retrieval), (b) component, which provides knew knowledge generation based on existing one (hereinafter known as knowledge discovery) and (c) component, which provides visualization of selected or discovered knowledge (hereinafter known as presentation layer).

¹⁰ Those subset elements are concerned with those output products, which meet the pre-defined criteria in a full range and cannot be repaired they can be good output products and are denoted as the waste output products.

BPF Internal Metrics			
Attributes of subsets a11, a21a, a21b, a31 a a41			
Attribute	IDENT	Description	Value measure unit
a11	[a11(i, 1)]	Employee content measure	
	[a11(i, 2)]	Labor performance	
a21a	[a21(i, 1)]	Success	
	[a21(i, 2)]	Appreciation	
	[a21(i, 3)]	The work alone	
	[a21(i, 4)]	Responsibility	
	[a21(i, 5)]	Growth and development possibility	
a21b	[a21(i, 6)]	Management policy	
	[a21(i, 7)]	Check and control	
	[a21(i, 8)]	Wages	
	[a21(i, 9)]	Interpersonal relations	
Source: The Authors.			

Table 1.
A content of [a11(i, j1)], [a21(i, j2)]), [a31(i, j3))] and [a41(i, j4)] linguistic subsets – the beginning.

BPF Internal Metrics			
Attributes of subsets a11, a21a, a21b, a31 a a41			
Attribute	IDENT	Description	Value measure unit
a31	[a31(i, 1)]	Economic conditions	
	[a31(i, 2)]	Organizational conditions	
	[a31(i, 3)]	Situation conditions	
	[a31(i, 4)]	Social conditions	
a41	[a41(i, 1)]	Physical capabilities	
	[a41(i, 2)]	Mental capabilities	
	[a41(i, 3)]	Health capabilities	
	[a41(i, 4)]	Theoretical knowledge	
	[a41(i, 5)]	Practical skills	
	[a41(i, 6)]	Individual features	
Source: The Authors.			

Table 2.
A content of [a11(i, j1)], [a21(i, j2)]), [a31(i, j3))] and [a41(i, j4)] linguistic subsets – the end.

4.3.4.1 KB content retrieval

The knowledge, which creates the knowledge base content is represented via semantic networks (see also section 4.2.3 and 4.2.4) and are directly interconnected with appropriate RDBs. On the other hand, the complex knowledge base is stored on any carrying medium, CD or DVD as for instance and the complete database is stored on more carrying media. Therefore, the medium with required knowledge should be determined, when searching required knowledge. This is possible to do via so called General requirement, which enables generating of adequate media list and storing it into selected file denoted as DISKINDEX. After having completed that operation, an appropriate Detailed requirement is being created, which enables retrieval of selected media content and generation of required knowledge list, while the presentation layer enables visualizing of the above-mentioned lists and detailed visualizing of selected knowledge, if necessary. A detailed description of those algorithms is over the contribution content and we shall not deal with it, as a result of that.

4.3.4.2 Knowledge discovery

The semantic networks, which represent newly discovered knowledge might be generated so that we change values of elements stored within appropriate linguistic sets and create new semantic networks, which represent newly discovered knowledge. The newly discovered knowledge is stored in an appropriate output file and visualized via presentation layer elements.

4.3.4.3 Presentation layer

The presentation layer is applied for visualization of selected or newly generated knowledge.

5. Conclusions

With respect to that contribution goal a set of qualitative relations between the investigated BP performance and the performance of employees interested in that BP functionality, from psychological point of view. This description created basis for determination of appropriate linguistic set content, which plays a role dominant importance, when preparing their quantitative representation, while a relationship among them is regulated by PBPL Equation. There was proposed a table and graphic solution of that equation and they created basis for design of semantic networks (see also section 4.2), which enable representation of knowledge stored within knowledge base, the proposed expert system operates over.

Our research for the near future is aimed to creation of adequate application program a its testing for practical application, especially in education, where we would like to test a relationship between content of university students within passing examinations and their mental performance as well.

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